

PeMS

The Freeway Performance Measurement System

Improving Management of the Freeways

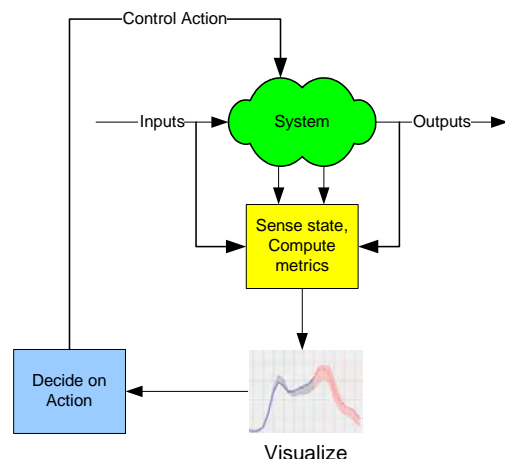
Karl Petty, Berkeley Transportation Systems, Inc.

June 15th, 2006



Systems Management

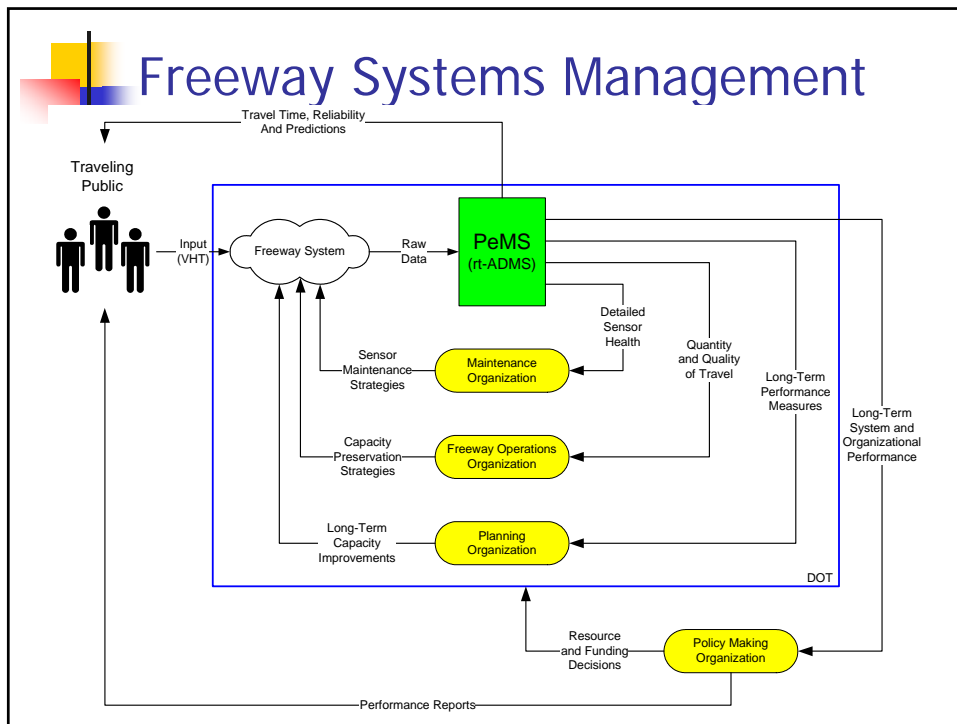
- Transportation network is a system
- At one level, vehicle hours are the input with vehicle miles as output
- There are many levels/types of inputs and outputs
- Proper collection and analysis of the outputs is necessary for efficient management and control



"If you cannot tell the VMT on your system yesterday, you cannot hope to manage your system today,"

Berkeley

attributed to Dolf May, 1961



What is PeMS?

- PeMS is a real-time Archive Data Management System (rt-ADMS)
- PeMS collects detailed freeway information
 - Fixed sensor: lane-by-lane, 20/30-second values
 - Incident: detailed reports
- Processes these values in real-time, performing:
 - Detector diagnostics
 - Imputation
 - Speed calculations
 - Aggregations
 - Performance measurement calculations
- Has a huge number of reports and tools
- Accessed via a browser
- In California:
 - Collects data from 9 districts (> 23,000 sensors)
 - Holds 4.5TB of data
 - 55 Billion samples/year

The screenshot shows the PeMS 5.4 California > HICOMP interface. The main table displays VMT data for 2004, categorized by District, Detector, and Time Period. The table includes columns for Year, Quantity, No. of Sensors, and % of Total.

Year	Quantity	No. of Sensors	% of Total
2004	Vehicle Miles Traveled		
2004	14,151,362.45	14,355,955.75	1.75
2004	15,351,824.73	15,553,346.37	1.31
2004	29,502,469.23	29,951,876.14	1.32
2004	16,792,629.56	17,165,267.16	1.19
2004	15,364,725.65	15,715,201.24	2.30
2004	10,150,195.07	10,377,475.54	2.34
2004	11,945,764.75	11,579,253.20	2.06
2004	9,949,179.04	10,095,422.99	1.51
2004	23,294,462.79	21,479,687.27	2.60
2004	82,956,209.08	84,810,107.95	1.87

PLEASE NOTE that these results are incomplete while we process historical data. They can be incomplete within a single district because we are not done with that district for the entire year, and they can be incomplete across districts because different time ranges have been processed in different districts. Please review our data inventory page for the current status for each district.



Using the PeMS Web Site

- Starting point is the Dashboards
 - Real-time Dashboard
 - Historical Dashboards
 - Detector Health
- PeMS Dashboard Characteristics
 - Actionable
 - Dashboards are tied to detailed analysis tools
 - Automatic
 - Based on data automatically collected and processed in real-time
 - Repeatable
 - Results are comparable over time and between districts
 - Internally focused
 - Meant to focus team and motivate action
 - But viewable by the public

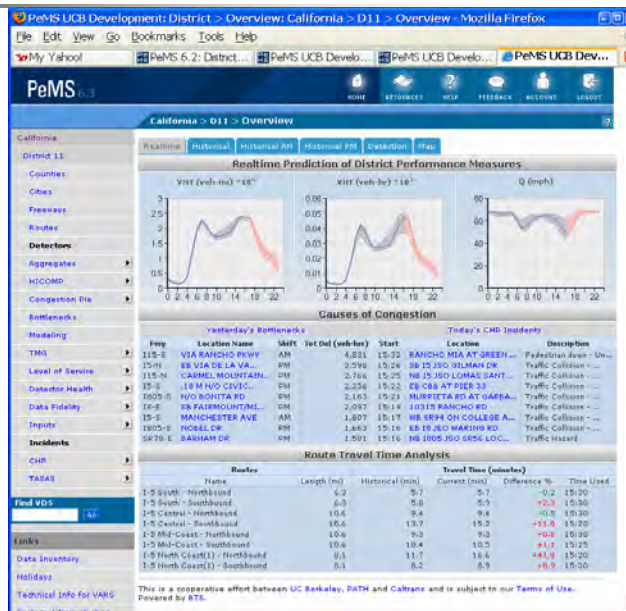
(Note: based on PeMS 6.3, to be released next week)

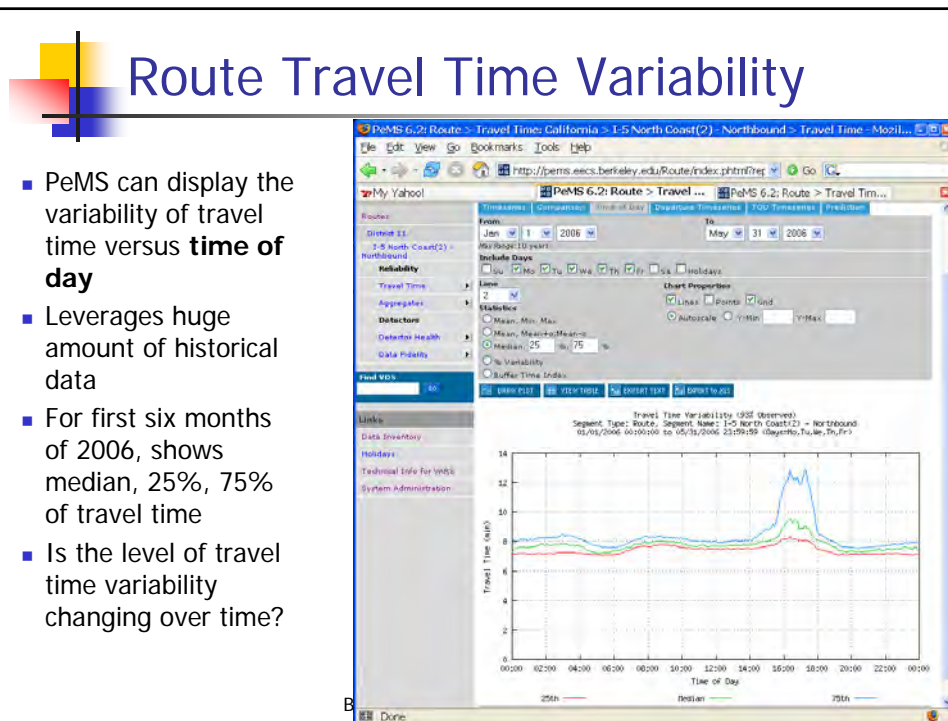
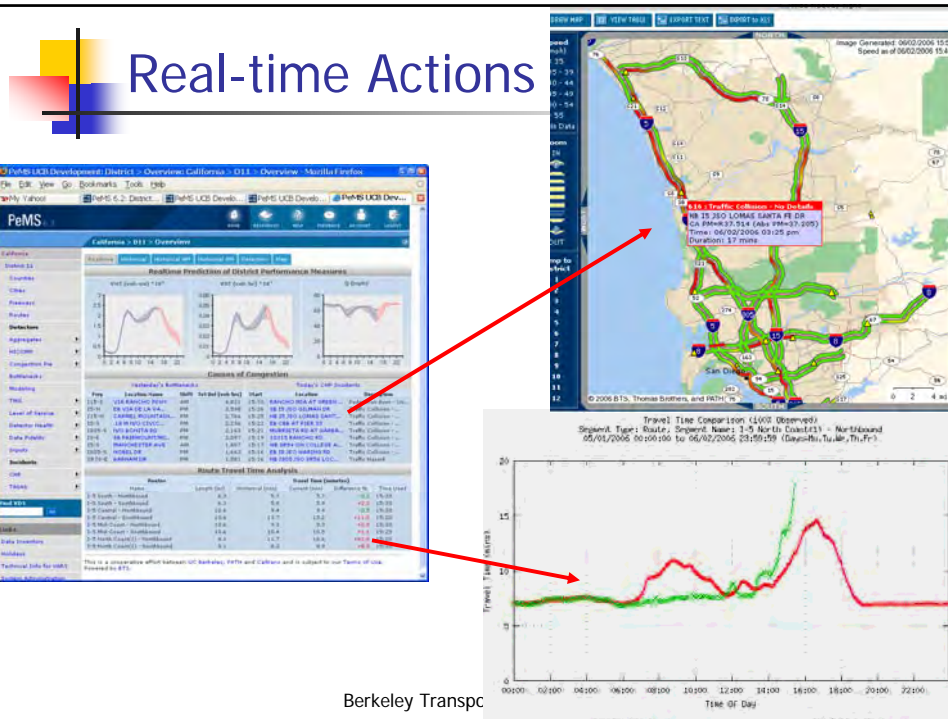
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Real-time Dashboard

- Caltrans D11
- Snapshot of what's taking place today
- Top: Traditional performance measures
 - Measured until now
 - Historical bounds
 - Predicted for rest of day
- Middle: Causes of congestion
 - List of major bottlenecks in District
 - List of incidents from CHP
- Bottom: Mobility analysis
 - Historical travel time
 - Latest available travel time
 - Difference

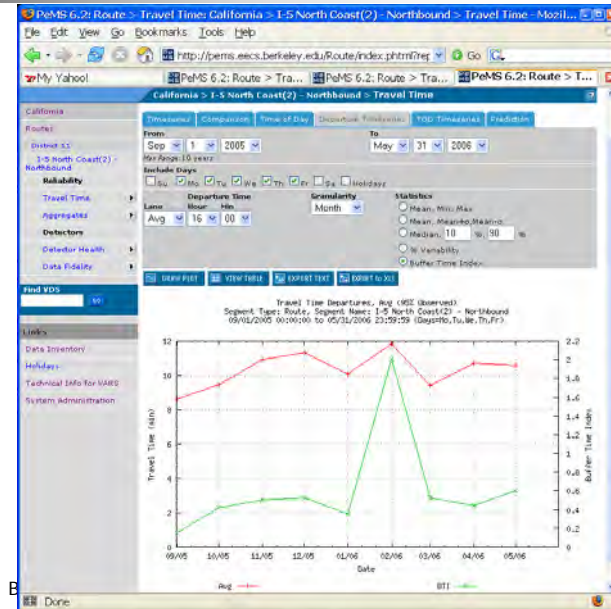






Route Travel Time Variability

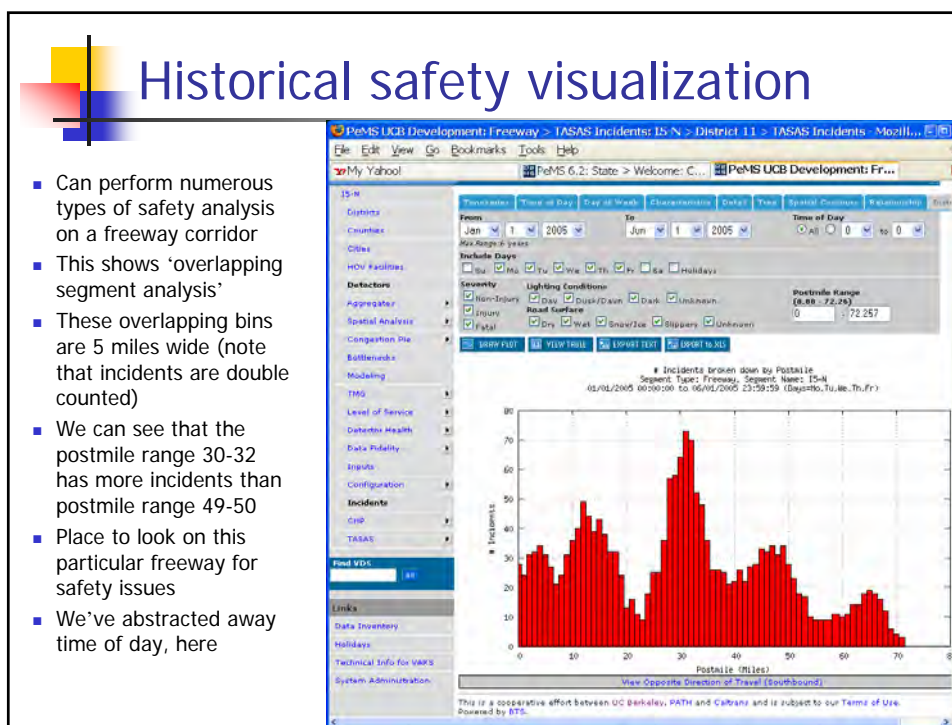
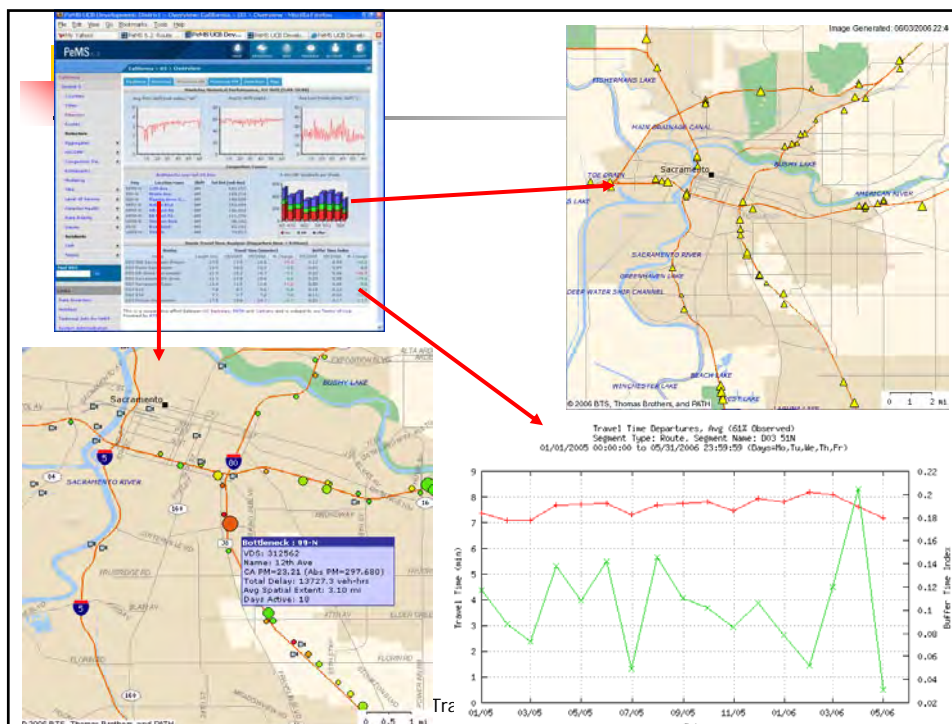
- This shows average travel time per month for last 9 months
- For a given departure time (4pm)
- Also plots Buffer Time Index (BTI): amount of extra time needed to complete route 95% of time, expressed as ratio to mean TT
- We can see that travel time and BTI are both generally increasing for this particular route



Historical Dashboard

- Focuses on only one shift (AM or PM), weekdays only
- Similar to real-time but for longer time periods
- Top: area-wide performance over last six months
 - VMT
 - VMT/VHT (Q)
 - Lost productivity
- Middle: Congestion causes
 - Bottlenecks
 - Incidents
- Bottom: Mobility analysis compared to last year
 - Average travel time for trips starting at 8:00am for the month
 - Buffer time index

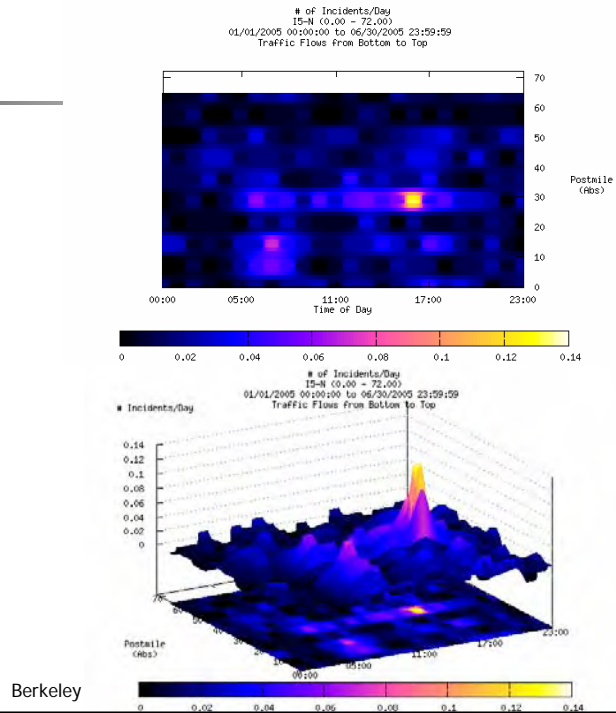






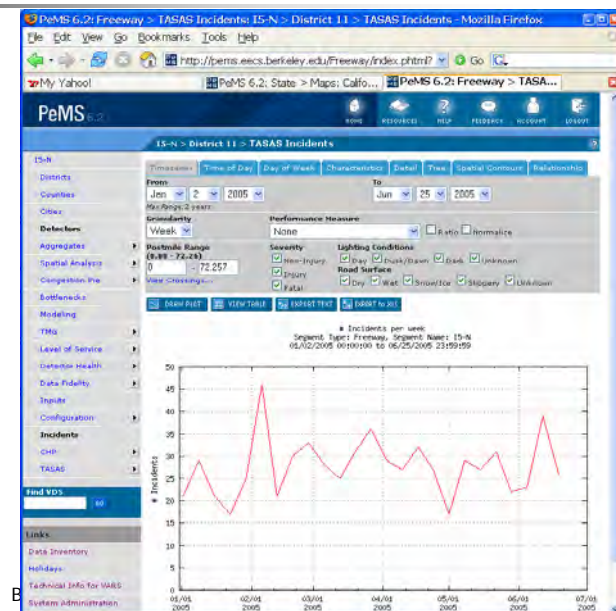
Safety

- For a freeway-direction we can also view the entire distribution over both space **and** time of day
- Top is a contour plot showing frequency of incidents for all weekdays
- Around postmile 30 from 4-5pm there is a spike in the incident rate
- Bottom plot is 3D version of top
- This is a summary for a long period of time, what about the temporal characteristics of incident rates?



Historical safety visualization

- We can plot incident counts over time
- This plot show incidents/week for this fwy-dir
- We can see a slight increase in the # of incidents over time
- Slope = +0.36%
- Nobody likes to see incidents going up
- We might have to redirect FSP resources if this trend continues
- But what's the relationship to the demand?

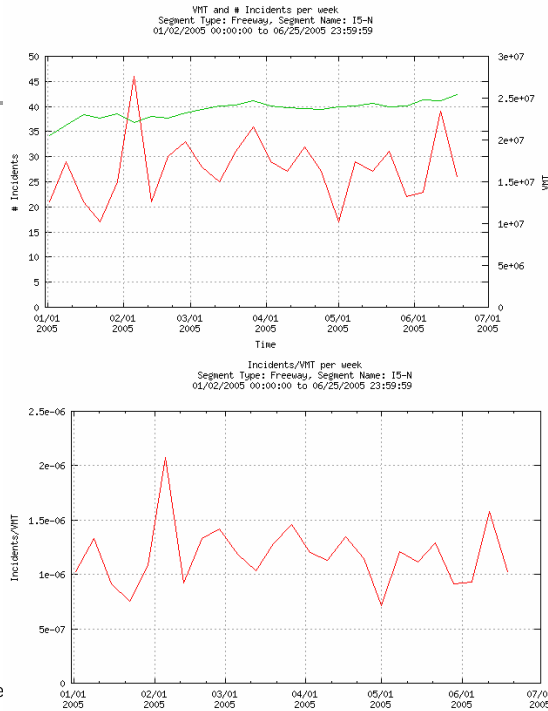




Safety

- We can add the traditional performance measure of VMT to the top plot
- We can see that demand is growing
- VMT slope = +0.56%
- On the bottom plot we have PeMS show the ratio of the # incidents to VMT
- Now incident **rate** is slightly decreasing
- # Incs/VMT slope = -0.17%
- Average of around 1.2×10^{-6} incidents/VMT
- Are these rates high versus other freeways in the district?

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Historical safety visualization

- This is the incident analysis table for the District
- This shows for every fwy-dir the number of incidents, a performance measure (VMT was selected), and the ratio
- We sort by the resulting ratio
- SR94-W has the highest incidents/vmt during this time period, 1.68incs/Mvmt
- I5-N is way down the list

PeMS 6.2: District > TASAS Incidents: California > D11 > TASAS Incidents - Mozilla Firefox

PeMS 6.2: District > TASAS...

California > D11 > TASAS Incidents

Summary: Timeframe: Time of day: Day of week: Characteristics: Detail: Year: Relationship

From: Jan 1 2005 To: Jun 30 2005

Max Range: 1 year

Include Data: ☒ Su ☒ Mo ☒ Tu ☒ We ☒ Th ☒ Fr ☒ Sa ☒ Holidays

Group By: Freeway

Performance Measure: Vehicle Miles Traveled (VMT)

Severity: ☒ Non-Injury ☒ Injury ☒ Fatal

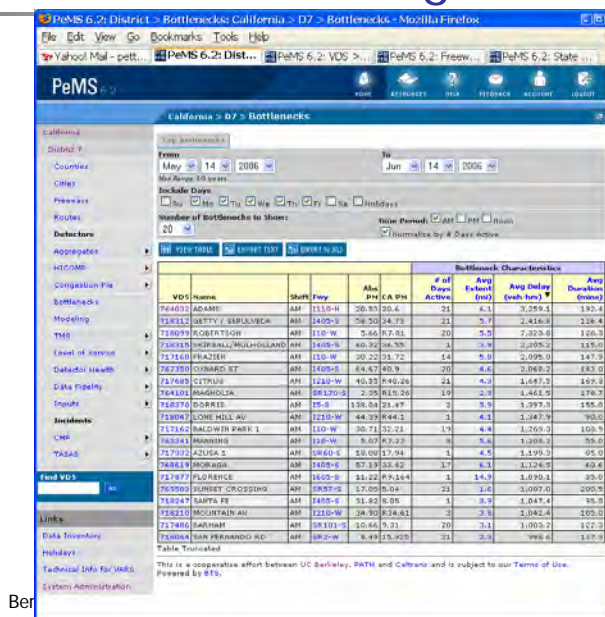
Lighting Conditions: ☒ Day ☒ Night ☒ Dark ☒ Unknown

Road Surface: ☒ Dry ☒ Wet ☒ Snow/Ice ☒ Slippery ☒ Unknown

Freeway	Frequency	Normalized	# Incidents	Inc/Freq	VMT	Inc/VMT	Normalized Inc/VMT	Data Quality	
								Observed	%
SR94-W	62.0	11.0	199	2.99	112.92	3.49	0.29	3,955,524	92.5
SR94-W	172.0	25.1	551	2.97	917.09	3.13	0.29	5,095,282	95.7
SR94-W	0.6	5.2	64	7.43	40.22	1.59	0.94	469,044	96.9
SR94-W	177.4	19.4	302	1.70	198.52	1.52	0.17	7,886,390	95.9
SR94-W	62.0	10.9	159	2.52	109.62	2.31	0.28	2,409,800	89.2
SR94-W	173.9	25.2	464	2.70	313.05	3.49	0.50	4,277,714	92.8
SR94-W	11.1	12.0	100	14.01	111.27	3.19	1.50	1,771,944	85.3
SR94-W	14.8	7.8	62	4.20	45.18	3.38	0.72	260,580	97.4
SR94-W	177.4	17.9	145	1.49	195.30	1.34	0.14	2,084,440	94.5
SR94-W	14.8	7.8	62	4.13	45.18	3.38	0.72	260,580	97.4
SR94-W	28.7	20.1	287	13.47	309.48	1.25	0.87	3,906,700	90.8
SR94-W	9.4	9.0	94	6.28	44.68	3.21	0.74	469,044	87.3
I5-S	72.2	42.1	820	11.40	605.02	1.20	0.70	6,027,196	94.7
I5-S	11.1	12.1	111	9.99	52.94	1.20	1.00	1,250,764	97.3
I5-N	72.2	42.0	715	9.30	609.49	1.17	0.69	4,742,256	93.2
I55-N	28.7	24.0	337	11.73	335.08	1.01	0.84	3,448,120	26.5
I15-S	84.5	42.1	534	9.00	550.97	0.95	0.74	6,206,026	89.4
I15-N	84.5	42.1	520	9.59	540.46	0.95	0.74	6,610,732	71.6
SR125-N	29.2	20.6	77	2.89	102.09	0.75	0.59	3,022,728	96.4
SR125-N	29.2	21.9	59	3.98	128.82	0.45	0.34	3,136,759	39.0

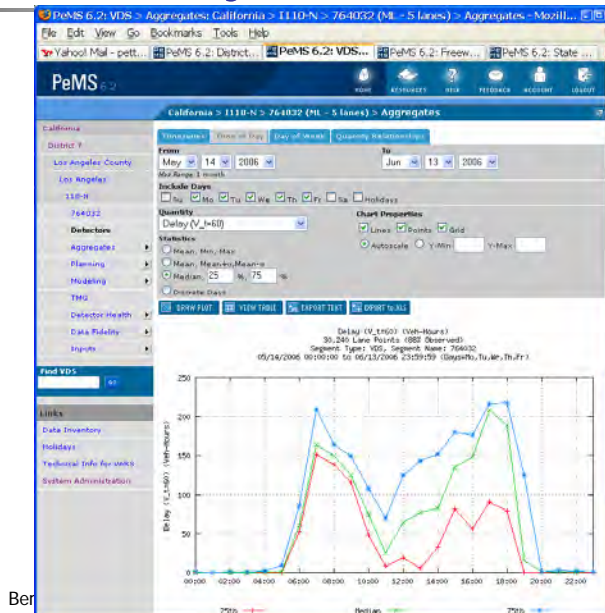
Bottleneck Identification Algorithm

- For a given region, show the sorted list of bottlenecks
- This shows in D11 (San Diego) all of the AM bottlenecks during the first two months of 2003
- Shows number of days bottleneck is active, spatial and temporal extent, and delay generated
- Links allow users to drill down to investigate characteristics and causes of bottlenecks



Bottlenecks – Delay

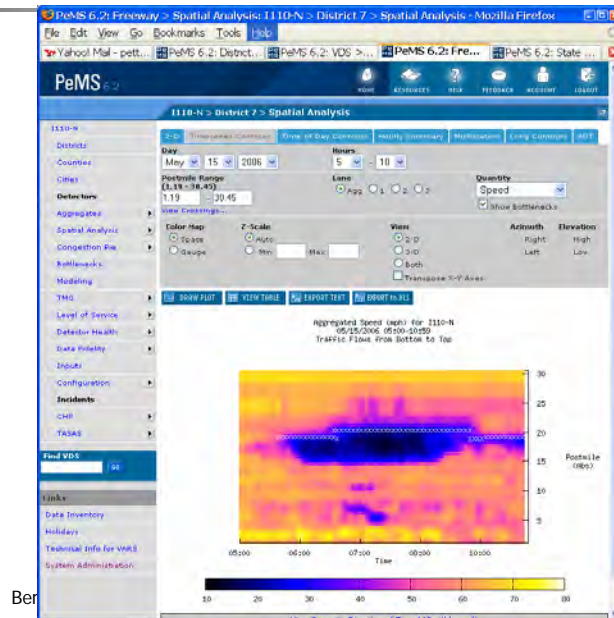
- Jumps to delay versus time of day for this location
- Can now see when the bottleneck starts and ends
- Allows users to investigate the variability of the bottleneck as it appears to users
- Is it a one-time event?
- In this example we can see that the AM bottleneck is very predictable – every day we have similar delay patterns





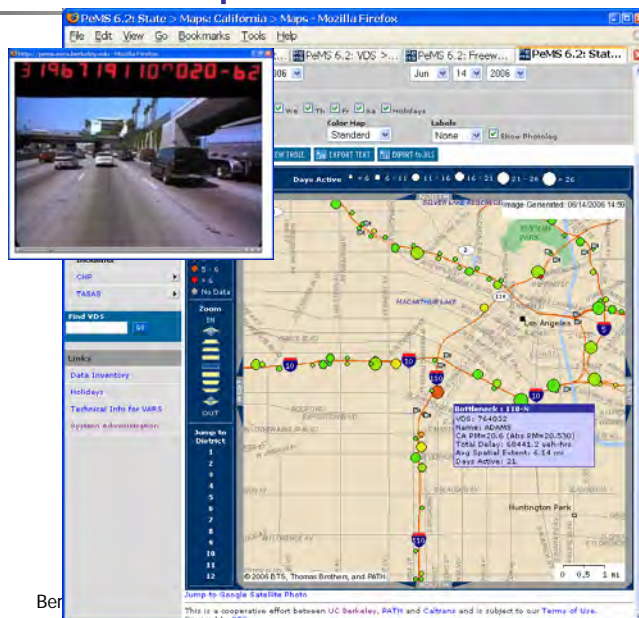
Bottlenecks – Contour Plots

- Jumps to spatial contour plots
- This is showing speed versus space and time
- Allows users to investigate the spatial and temporal extent of the bottleneck on a single day
- We mark on the plot where we think the bottleneck was activated for this day



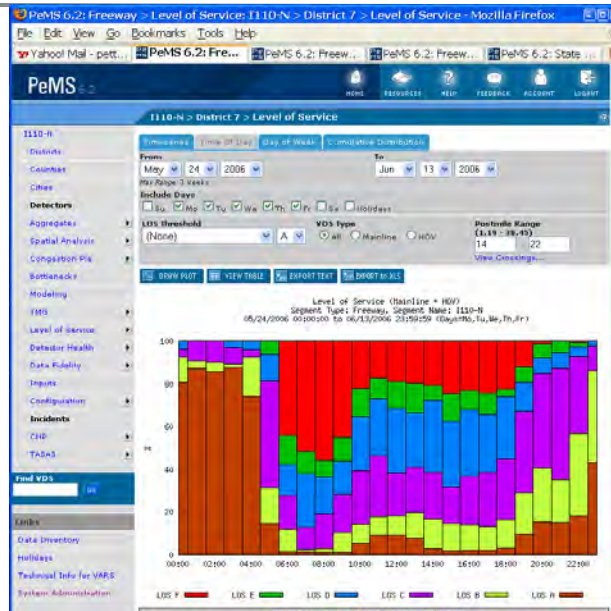
Bottlenecks – Maps

- Can jump to a map view of the location of the bottleneck
- We color and size the dots according to the delay caused and the number of days activated
- For Caltrans we tie map to other types of media
- They have a video record of every freeway in the state (PhotoLog)
- Users can see the bottleneck through these movies



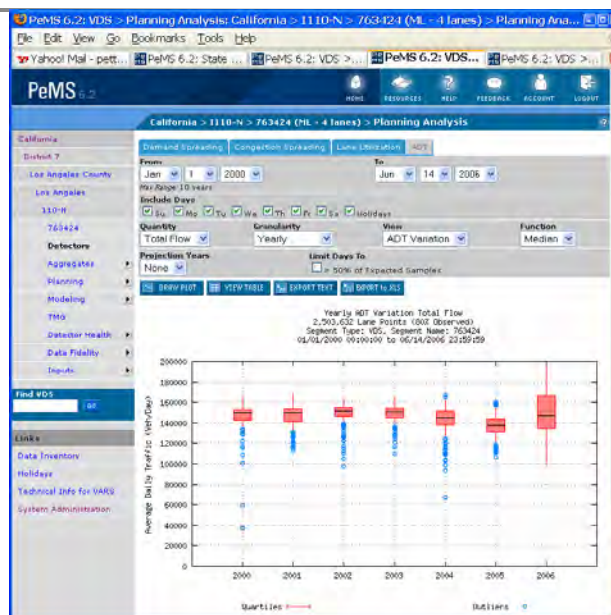
Bottlenecks – Level of Service

- Ability to perform many types of common transportation planning analysis functions
- Shows breakdown of Level of Service (LOS) over 110N from the 105 to the 10 during weekdays
- LOS ranges from A-F and represents driving conditions
- “A” is completely clear; “F” is completely packed
- We can see that the worst conditions are during the morning rush hour
- Can see the percentage of drivers experiencing each level of service



Bottlenecks – AADT

- Can investigate changes in demand at locations upstream of bottleneck
- Shows AADT per year for 1/2000 – 5/2006
- These are based on measured values, not sample counts and factor groups
- Excellent input for growth models
- Can see steady ADT over time
- Can see all of the holidays as outliers



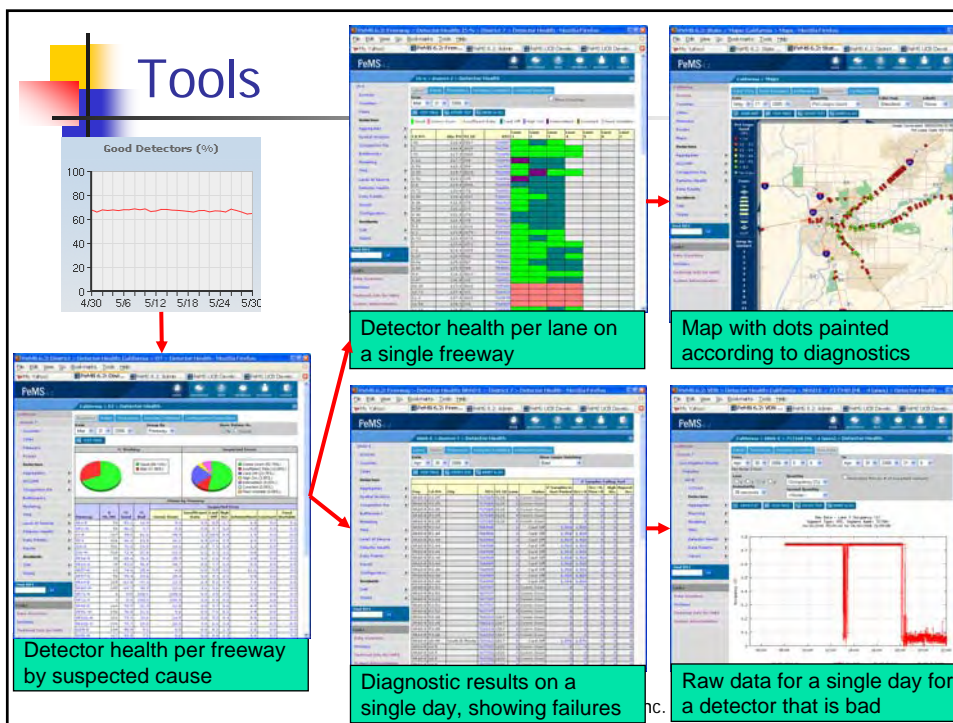


Detection Health Dashboard

- Combines real-time and historical values together
- Top: real-time
 - Samples collected today
 - Current detector health
 - Breakdown of reasons why
- Bottom: historical
 - Samples collected over time
 - Health over time
 - Reasons bad over time
- Allows for real-time actions and can see the trend of how well the district is doing over time
- This particular district, D11, has the best data quality in the State



Tools





Freeway Segments for SANDAG

- Wanted the ability to track performance measures for a particular section of freeway over long periods of time
 - PeMS originally did this but it was cumbersome
 - UI wasn't designed for this task
 - Reports took too long to generate
 - Database wasn't designed for this task
- We implemented a new feature for SANDAG
 - Extended system to understand "Segments" (routes)
 - Predefined postmile range on the freeway system
 - Extended processing and database to store calculated information about routes in real-time
 - Subsequent plots are much faster
 - Enhanced user interface to generate new reports
- Allowed for easy comparison between their segmentation and the way PeMS reports performance measures

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Freeway Routes Table

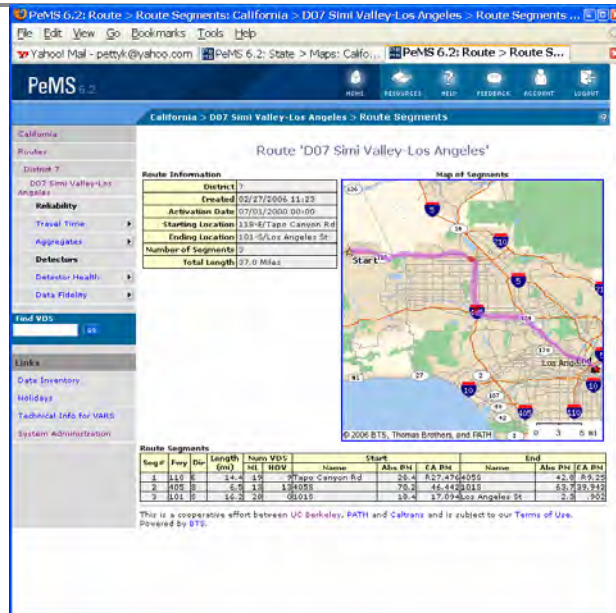
- A number of routes were predefined
- These matched their segmentation
- Typically from freeway to freeway
- We've extended this feature to include any route through the system
- Once it was done for one region, everybody in the State got it
- We now have routes for D7...

Route Name	From	To	Total Miles	# VLS	# RV	# VDS/Mile
I-15 Far North - Northbound	SR 78	Riverside ...	22.7	1	0	0.04
I-15 Far North - Southbound	Riverside ...	SR 78	22.7	3	0	0.04
I-15 Far South - Northbound	I-5	SR 163	12.2	13	0	1.06
I-15 Far South - Southbound	SR 163	I-5	12.2	11	0	0.90
I-15 Middle - Northbound	SR 56	Centre Cit...	8.2	7	0	0.86
I-15 Middle - Southbound	Centre Cit...	SR 56	8.2	7	0	0.86
I-15 North - Northbound	Centre Cit...	SR 78	3.9	4	0	1.03
I-15 North - Southbound	SR 78	Centre Cit...	3.9	3	0	0.78
I-15 South - Northbound	SR 163	SR 56	7.4	7	3	1.36
I-15 South - Southbound	SR 56	SR 163	7.4	8	2	1.50
I-5 Central - Northbound	SR 54	I-8	10.6	14	0	1.32
I-5 Central - Southbound	I-8	SR 54	10.6	11	0	1.03
I-5 Far North - Northbound	SR 76	Orange Cou...	18.4	0	0	0.00
I-5 Far North - Southbound	Orange Cou...	SR 76	18.4	0	0	0.00
I-5 Mid-Coast - Northbound	I-8	I-805	10.6	11	0	1.04
I-5 Mid-Coast - Southbound	I-805	I-8	10.6	13	0	1.22
I-5 North Coast(1) - Northbound	I-805	Manchester...	9.1	7	1	0.99
I-5 North Coast(1) - Southbound	Manchester...	I-805	9.1	7	0	0.97
I-5 North Coast(2) - Northbound	Manchester...	Palomar Ai...	9.5	7	0	0.93
I-5 North Coast(2) - Southbound	Palomar Ai...	Manchester...	9.5	7	0	0.93
I-5 North Coast(3) - Northbound	Palomar Ai...	SR 76	6.7	3	0	0.45
I-5 North Coast(3) - Southbound	SR 76	Palomar Ai...	6.7	7	0	1.05
I-5 South - Northbound	SR 905	SR 54	6.3	5	0	0.79
I-5 South - Southbound	SR 54	SR 905	6.3	5	0	0.79
I-8 East - Eastbound	Murray Blv...	2nd Street	8.0	9	0	1.12
I-8 East - Westbound	2nd Street	Murray Blv...	8.0	13	0	1.62
I-8 West - Eastbound	Murray Blv...	I-5	9.7	13	0	1.34
I-8 West - Westbound	I-5	Murray Blv...	9.7	13	0	1.24
I-805 Middle - Northbound	SR 54	I-8	8.8	8	0	0.91
I-805 Middle - Southbound	I-8	SR 54	8.8	8	0	0.91
I-805 North - Northbound	I-8	I-5 (North...	10.9	8	0	0.74
I-805 North - Southbound	I-5 (North...	I-8	10.9	10	0	0.92



Freeway Segments (Routes)

- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Total of 37 miles
- We compute a number of performance measures for this route
- Travel time for every time of the day
 - Can use this to calculate reliability
- Traditional freeway performance measures (delay, vmt, vht, etc).



Route Travel Time Analysis

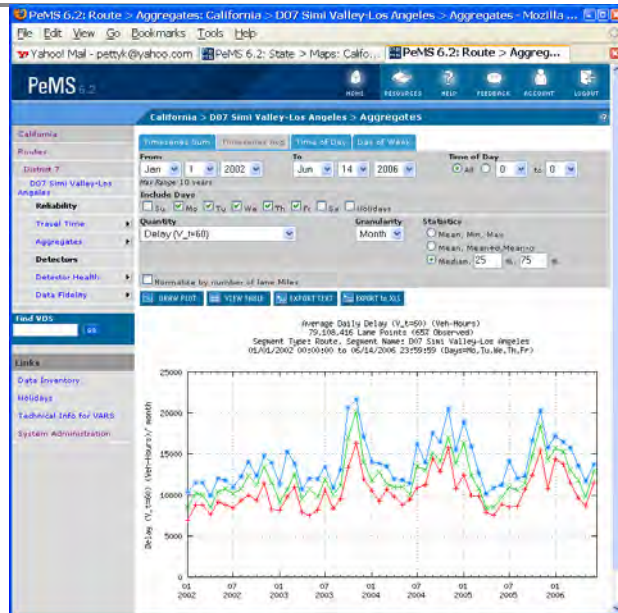
- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Shows average travel time for route starting at 6am during the weekdays
- Each point is the average for an entire quarter
- Covers the time period of 1/2002 – 6/2006
- Green line shows travel time reliability measure of Buffer Time Index (BTI): amount of extra time needed to complete route 95% of time, expressed as ratio to mean TT
- Can clearly see seasonal trends





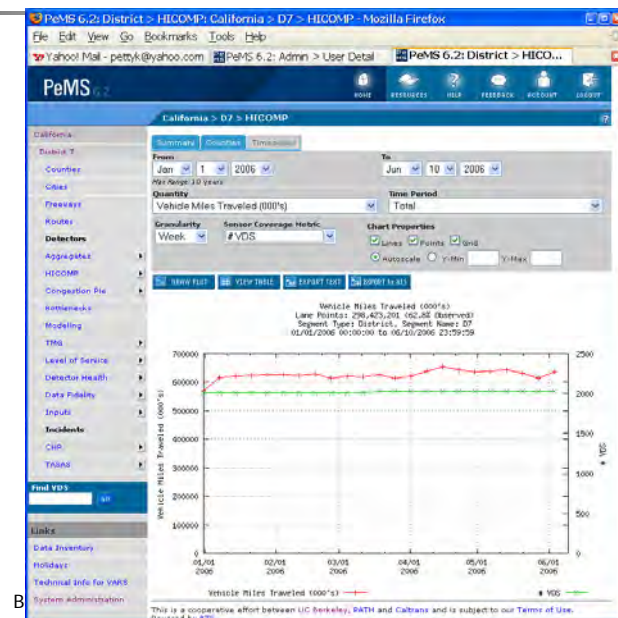
Route Performance Analysis

- Route: Simi Valley to Downtown (118 -> 405 -> 101)
- Show traditional freeway performance measure of delay (vehicle-hours)
- Shows average delay per month for weekdays along the route (along with 25% and 75% of distribution)
- Can clearly see the same seasonal variation that was in the route travel time plot



D7 VMT?

- We compute traditional performance measures, including VMT, for spatial segments (freeways, counties, districts, state)
- This plot shows the total VMT per week for all of D7 during 2006
- We also plot the number of detectors in the system (make sure we're measuring the same freeways)
- There is no drop in total VMT





Summary

PeMS is a Real-time Archive Data Management System

- Focused on helping agencies plan for operations
- Allows for direct empirical measurements of freeway performance
- Links together
 - Traffic data archival systems
 - Real-time operational strategies
 - Freeway performance measurement

System is extendable!

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